NASA Glory

Aerosol Polarimetry Sensor

Level 0 Data Description

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1 Aerosol Polarimetry Sensor Overview

1.1 Sensor Description

The Aerosol Polarimetry Sensor (APS) collects global aerosol data based on along-track, sub-satellite polarimetric measurements taken within the solar reflective spectral region (0.4 to 2.4 microns). Measurements of spectral radiance are restricted to the sunlit portion of the orbit and, since clouds can have a significant impact on the analysis of polarimetric measurements the cloud cameras on the Glory satellite are also used to distinguish between clear and cloud filled scenes. The three-year mission life (five-year goal) provides the minimum duration to observe seasonal and regional trends and characterize the evolution of aerosols during transient climate events (El Niño, volcanic eruptions, etc.).

The APS instrument collects data over 9 spectral bands with wavelengths at 412 nm, 443 nm, 555 nm, 672 nm, 865 nm, 910 nm, 1378 nm, 1610 nm and 2250 nm. The first six bands are in the visible and near infrared (VNIR) and operate at ambient temperatures, while the last three are in the short wave infrared (SWIR) and are cooled to a selectable set point between 155 and 165K. For each band, data is collected at 4 polarization angles; 0°, 45°, 90° and 135°. The data for each polarization angle flows along an electro-optical channel, so that there are 36 channels altogether. Data from the 0° and 90° channels are processed together and similarly the 45° and 135° channels. For each band, the channels for 0° and 90° are a conjugate pair, as are the channels for 45° and 135°. The instantaneous field of view (IFOV) of the APS is 8±0.1 mrad (with eccentricity of less than 1.5%) which gives a ground footprint at nadir from the 705 km orbit of 6.5 km.

To maintain polarization accuracy over the life of the mission APS can be calibrated on orbit and has four references for this purpose; the dark reference, the solar reference and the polarized and unpolarized references. These are sampled every scan along with the scene data.

APS completes one scan approximately every 1.47 seconds, and orbits the earth approximately every 100 minutes.

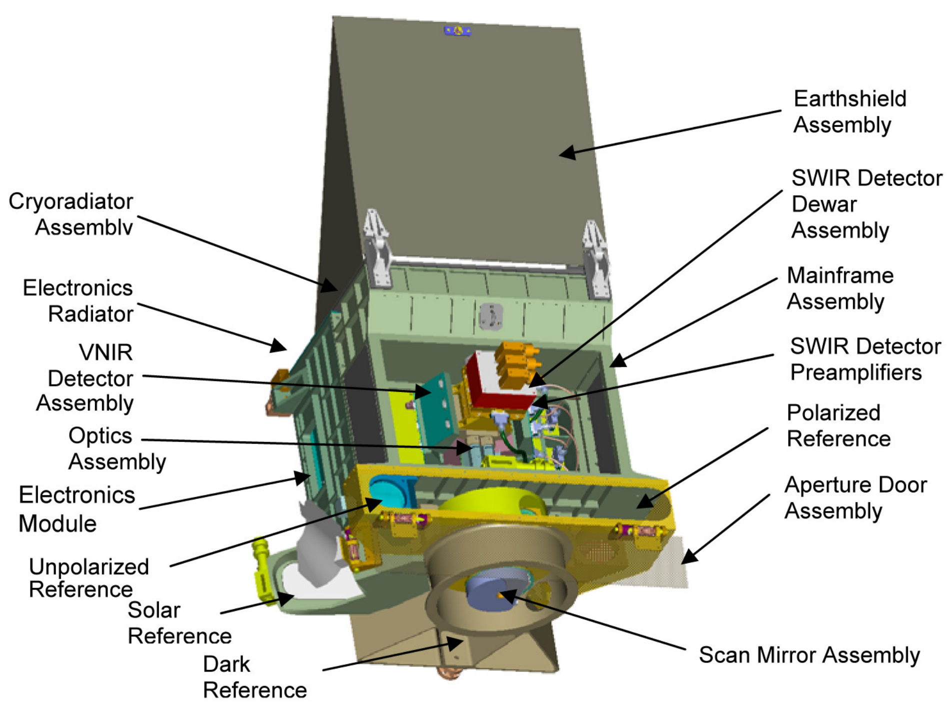

Figure 1. APS Components – For reference only.

Figure 1 illustrates the major components of the APS. The orientation of the illustration may be best understood by realizing that the earth shield assembly protects the cryoradiator from radiation from the earth and its main surface is parallel to the earth surface and the spacecraft surface.

The Scan Mirror Assembly (SMA) is at the bottom of Figure 1. The dark reference is on the spacecraft side of the SMA, opposite the earth view. The other references are arranged around the SMA as shown. The exact locations of the reference assemblies around the APS scan with respect to nadir are given in Table I. The term sector is used to designate a particular view angle and the entire scan is split into exactly 768 sectors which means that the centers of the sectors are space 8.18 mrad apart.

Table I. Locations of reference assemblies around the APS scan with respect to nadir view.

Scene	Behavior	Relative to nadir				Sectors
		Start Sector	End Sector	Angle Start	Angle End	
DRA[1]	Restore	-336	-327	-157.5	-153.3	10
DRA[2]	Sampling	-326	-311	-152.8	-145.8	16
PRA	Sampling	-211	-205	-98.9	-96.1	7
Earth[4]	Sampling	-115	139	-53.9	65.2	255
URA	Sampling	177	187	83.0	87.7	11
SRA	Sampling	282	298	132.2	139.7	17
DRA[3]	Sampling	407	422	190.8	197.8	16
DRA	Restore	N/A	N/A	N/A	N/A	Resync
Total	N/A	N/A	N/A	N/A	N/A	322

Notes: See Section 1.3.2.7 for a description of what the DC restore is. 1) This where the DC restore occurs and is the zero for internal logic. 2) This data is designated post-DC restore. 3) This data is designated pre-DC restore since it occurs at the end of a scan after scene data has been acquired and before the DC restore occurs. 4) It should be noted that the first seven sectors in the Earth scene are at least partially vignetted and so valid Earth view data starts at a sector -108 from nadir at a view angle of -50.6° from nadir as measured at the satellite.

The APS is synchronized to the spacecraft time using the APS Attitude Control System (ACS) status packets from the spacecraft and the 1PPS. The APS ACS status packet contains the Time of Day (TOD) of the next 1PPS. The APS resets its internal clock to the TOD in the APS ACS status packet at the next 1PPS.

The APS has separate power feeds from the spacecraft: OPERATIONAL power for the APS electronics and OPERATIONAL HEATER power used to heat the motor and ODM during the normal operation of the APS, ODM TRIM HEATER and SURVIVAL HEATER to provide power to the ODM trim heater and survival heaters to prevent the APS from getting too cold, and two latch power supplies for the one time operation of the door latches (Aperture Door and Solar Reference Door).

The main sub-systems of the APS are the:

Electronics Module (EM): Includes all the APS electronics (signal processing, analog to digital conversion, data formatting and power conditioning) except for the pre-amplifiers which are located with the detectors.

Optics Detector Module (ODM): Includes all the APS optics except for the scan mirror motor assembly including the SWIR Detector Dewar Assembly (SDDA) which allows the SWIR detectors to be cooled by a passive cryo-radiator, relay telescopes, Wollaston prisms, dichroic beam splitters, IAD filters, detectors and pre-amplifiers.

Scan Mirror Motor Assembly (SMMA): Includes the SMA, motor and the APS calibrators which are the Dark Reference Assembly (DRA), Solar Reference Assembly (SRA), Unpolarized Reference Assembly (URA) and the Polarized Reference Assembly (PRA).

The structure into which all these assemblies are mounted is called the Main Frame (MF) assembly.

1.2 Modes and States

The APS has three modes: SAFE, OPERATIONAL and OFF. When power is applied, the APS will be in SAFE mode. The location of the scan mirror is unknown during transitions and immediately after power-up post launch. The APS has three states: ODMTRIM, SURVIVAL, and STOWED that can occur while in different modes. States are controlled by the via the spacecraft power bus or, in the case of the STOWED state, by commands.

1.2.1 Off Mode

When no OPERATIONAL power is supplied to the APS, it is in OFF mode irrespective of the state of any of the other power feeds. Passive temperature telemetry may be monitored by the spacecraft, survival power may be applied, outgassing may occur, and door latches may be released.

1.2.2 Safe Mode

The APS enters SAFE under three conditions: when OPERATIONAL power is supplied, by command, or when autonomous SAFE is enabled and executed. Autonomous SAFE is executed as a result of 3 lost APS ACS status packets.

OPERATIONAL HEATER power is to be supplied at the same time as the OPERATIONAL power to ensure that 1) the motor bearing will be warm enough to turn when the OPERATIONAL mode command is sent and 2) that the optics are kept at a sufficiently steady temperature for the science data to be acceptable.

When OPERATIONAL power is initially supplied autonomous SAFE is disabled.

When OPERATIONAL power is initially applied the scan mirror is in an unknown position, but once the instrument has been scanning in OPERATIONAL mode for 22 seconds and then been in the SAFE mode for 22 seconds the scan mirror is stowed. Telemetry while in STOW will indicate that the scan mirror is pointing at the dark reference. Although the requirement for stowing the mirror is for 22 seconds after a SAFE command, once the APS is operational, the scan mirror actually stops within a single scan and so the scan mirrors will be properly stowed provided the APS is powered for 2 seconds after SAFE command is received.

In SAFE mode, both passive telemetry and telemetry are available and valid. Science data packets are also available but the scan mirror is stationary and therefore the data will be from the fixed stowed position sampling the Dark Reference. The SAFE mode data therefore provides valid data for evaluation dark reference stability and dark noise.

While in SAFE mode the spacecraft may supply ODM trim heater power and survival power.

1.2.3 Operational Mode

The APS enters the OPERATIONAL mode only on command.

The OPERATIONAL mode command should not be sent unless the temperature telemetry from the motor bearings indicates that they are warm enough to be turned on. The bearings should be at least 5°C.

When the OPERATIONAL mode command is received, the scanner starts scanning and data is collected from the dark reference, the polarized reference, the earth view, the unpolarized reference, the solar reference, and the dark reference.

Passive telemetry, telemetry, and science data are all provided and valid.

ODM trim heater power and survival power can be applied and it is expected that the ODM trim heater will be operated continuously in order for the ODM to operate at the preferred temperature of 20°C. The survival power, even if applied is unlikely to be operating during normal operations because the thermostatic switches which enable the heaters have set points that are lower than the expected on orbit temperatures.

1.2.4 ODMTrim State

The APS has one trim heater located on the Optics and Detector Module (ODM). ODM trim heater power is under direct control of the spacecraft, and the APS has no means of monitoring the state of the ODM trim heater power bus.

1.2.5 Survival State

Survival power is under direct control of the spacecraft, and the APS has no means of monitoring the state of the survival power bus. For the APS to draw SURVIVAL power via engaged APS thermostatic switches, the SURVIVAL state must be active.

The APS has three sets (primary and redundant) of survival heaters. One set is located on the ODM and the other two sets are located on the mainframe (MF) bulkhead (one closest to the polarized reference – PR - , the other closest to the unpolarized reference – UR -). For each survival heater, APS has two thermostatic switches in series to ensure that the SURVIVAL power will only be drawn when the temperature falls below certain set points. These set points are different for primary and redundant survival circuits to ensure that primary and redundant power is not drawn simultaneously if both survival heater circuits are active. Temperature set points are delineated in Table I.

Table II. APS Thermostatic Switch set points

		Thermostatic Switches			
		Primary		Redundant	
		ON	OFF	ON	OFF
Operational Heaters	Motor	8°C	17°C	8°C	17°C
Survival Heaters	ODM	-17°C	-12°C	-20°C	-15°C
	MF PR	-17°C	-12°C	-20°C	-15°C
	MF UR	-17°C	-12°C	-20°C	-15°C

All heaters have been tested at sensor and spacecraft level except the ODM redundant survival heater for which the thermostatic switch has never been activated with the lowest temperature achieved during testing being -22°C. The thermostatic switches generally activate at a temperature 2-3°C lower than their nominal set point the first time they are used. Since the ODM contains crystal optics that, at the time of sensor testing had only been tested to -20°C, it was considered an unnecessary risk to test this heater at colder temperatures. This does not represent a risk to the ODM because in order to get the ODM to -22°C both MF heaters had to be de-activated. These heaters will be activated when APS is in survival state on orbit and it is unlikely that the APS will ever experience temperatures that would allow the redundant ODM survival heater to operate.

1.2.6 Stowed State

The APS is said to be in a STOWED state when the position of the scan mirror is known in SAFE mode such that the optical line-of-sight is stationary and directed at the center of the Dark Reference. The STOW telemetry indicates that the mirror has stopped within the 18-degree index pulse sector which is approximately aligned with the Dark Reference position.

To enter the STOWED state, the APS transitions to SAFE mode from the OPERATIONAL mode (allowing up to 22 seconds for each mode transition, although actual transition time is a little less than 1.5seconds).

1.3 Control of APS

1.3.1 Spacecraft Control

The spacecraft supplies power to APS for normal operation, operational heater power, survival heating, and releasing latches. Normal operation is powered by the OPERATIONAL power and OPERATIONAL HEATER power buses.

In normal operation the APS will use less than 55W (orbit average) of OPERATIONAL power and OPERATIONAL HEATER power in either SAFE or OPERATIONAL modes.

1.3.2 Commands

The APS has 8 commands that are used on orbit:

1. Mode
2. Integration Time
3. Science Data Collect
4. SDDA Temperature
5. Test Data
6. Autonomous SAFE
7. DC Restore Inhibit
8. DC Restore Active

1.3.2.1 Mode Command

This command commands the APS to go to a specific mode, either SAFE or OPERATIONAL. The default on power up is SAFE. When the OPERATIONAL mode is commanded the scanner automatically starts to scan.

1.3.2.2 Integration Time Command

The APS integrates each signal over a time interval, the same interval for all bands. This interval can be changed on command but only between three set values. The default value is the middle time interval. The command allows the interval to either be increased or decreased but only to particular set points. This provides the ability to increase the signals (for example if the scene were dimmer than expected) by integrating for longer, or reducing the signals (for example if the input were saturating the electronics) by integrating for less time. The nominal (default) integration time is 0.96 msec. The other integration times have also been tested and based on APS observations at multiple radiance levels the other integration times have a length relative to the nominal time of 1.2034±0.0005 for the longer integration time and 0.7969±0.0012 for the shorter integration time.

1.3.2.3 Science Data Collect Command

The APS can have the science data collection disabled. The default is enabled even when not scanning.

1.3.2.4 SDDA Temperature Command

This APS command controls the SDDA temperature to a particular set point. The value of the set point is not critical but it must be below 170K and stable. Over time the SDDA temperature control system may change and therefore three temperature set points have been implemented as well as OFF. The default value is OFF. This command allows the temperature set point to be commanded to OFF, 155K, 160K or 165K. It is expected that at the start of the mission the APS will operate at 155 K and as thermal surfaces degraded and the sensor gets warmer higher set points will be used in order to ensure thermal control is achieved. Adequate SNR is actually achieved once the detectors are cooler than 200 K.

1.3.2.5 Test Data Command

The APS has a stored science data test pattern which may be used to test the APS data path from the digital processor to the 1553 bus. While this test pattern is enabled, science data is unavailable since the test pattern replaces the signal processor (i.e. detector) data.

This test pattern is enabled by command and is disabled by default. This command has a red alarm associated with its execution on orbit to ensure that it is only used for resolution of anomalies.

The format of the science data test pattern is defined in Figure 2.

<table>
<tr><td>MSB</td><td colspan="14"></td><td>LSB</td></tr>
<tr><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="10">Position_in_Scan</td><td colspan="2">MUX</td><td colspan="4">Band</td></tr>
</table>

Figure 2. APS science data test pattern format.

Position in scan: is a number from 0 to 767and indicates from which number sample (view angle) the data originated.

MUX: is a number between 0 and 3 indicating from which MUX position (polarization orientation, 0, 45 ,90, 135°) the data originated.

Band is a value from 1 to 9 and indicates from which ADC (band) the data originated.

The following is an abridgement of the received test pattern data:

Sample 1:
```
0x0281 0x0282 0x0283 0x0284 0x0285 0x0286 0x0287 0x0288 0x0289 0x0291 0x0292 0x0293 0x0294 0x0295
0x0296 0x0297 0x0298 0x0299 0x02A1 0x02A2 0x02A3 0x02A4 0x02A5 0x02A6 0x02A7 0x02A8 0x02A9 0x02B1
0x02B2 0x02B3 0x02B4 0x02B5 0x02B6 0x02B7 0x02B8 0x02B9
```
Sample 2:
```
0x02C1 0x02C2 0x02C3 0x02C4 0x02C5 0x02C6 0x02C7 0x02C8 0x02C9 0x02D1 0x02D2 0x02D3 0x02D4 0x02D5
0x02D6 0x02D7 0x02D8 0x02D9 0x02E1 0x02E2 0x02E3 0x02E4 0x02E5 0x02E6 0x02E7 0x02E8 0x02E9 0x02F1
0x02F2 0x02F3 0x02F4 0x02F5 0x02F6 0x02F7 0x02F8 0x02F9
```
Sample 3:
```
0x0301 0x0302 0x0303 0x0304 0x0305 0x0306 0x0307 0x0308 0x0309 0x0311 0x0312 0x0313 0x0314 0x0315
0x0316 0x0317 0x0318 0x0319 0x0321 0x0322 0x0323 0x0324 0x0325 0x0326 0x0327 0x0328 0x0329 0x0331
0x0332 0x0333 0x0334 0x0335 0x0336 0x0337 0x0338 0x0339 ......
```
Sample 16:
```
0x0681 0x0682 0x0683 0x0684 0x0685 0x0686 0x0687 0x0688 0x0689 0x0691 0x0312 0x0313 0x0314 0x0315
0x0316 0x0317 0x0318 0x0699 0x06A1 0x06B2 0x06B3 0x06B4 0x06B5 0x06B6 0x06B7 0x06B8 0x06A9 0x06B1
0x06B2 0x06B3 0x06B4 0x06B5 0x06B6 0x06B7 0x06B8 0x06B9
```
Sample 17:
```
0x1F41 0x1F42 0x1F43 0x1F44 0x1F45 0x1F46 0x1F47 0x1F48 0x1F49 0x1F51 0x1F52 0x1F53 0x1F54 0x1F55
0x1F56 0x1F57 0x1F58 0x1F59 0x1F61 0x1F62 0x1F63 0x1F64 0x1F65 0x1F66 0x1F67 0x1F68 0x1F69 0x1F71
0x1F72 0x1F73 0x1F74 0x1F75 0x1F76 0x1F77 0x1F78 0x1F79 ...........
```
Sample 321:
```
0xBD41 0xBD42 0xBD43 0xBD44 0xBD45 0xBD46 0xBD47 0xBD48 0xBD49 0xBD51 0xBD52 0xBD53 0xBD54 0xBD55
0xBD56 0xBD57 0xBD58 0xBD59 0xBD61 0xBD62 0xBD63 0xBD64 0xBD65 0xBD66 0xBD67 0xBD68 0xBD69 0xBD71
```

```
0xBD72 0xBD73 0xBD74 0xBD75 0xBD76 0xBD77 0xBD78 0xBD79
```
Sample 322:
```
0xBD81 0xBD82 0xBD83 0xBD84 0xBD85 0xBD86 0xBD87 0xBD88 0xBD89 0xBD91 0xBD92 0xBD93 0xBD94 0xBD95
0xBD96 0xBD97 0xBD98 0xBD99 0xBDA1 0xBDA2 0xBDA3 0xBDA4 0xBDA5 0xBDA6 0xBDA7 0xBDA8 0xBDA9 0xBDB1
0xBDB2 0xBDB3 0xBDB4 0xBDB5 0xBDB6 0xBDB7 0xBDB8 0xBDB9
```

1.3.2.6 Autonomous Safe Command

The APS can be enabled to go to SAFE autonomously when 3 consecutive APS ACS packets have been missed. This is disabled by default, but when the APS is initialized for operational data acquisition it is enabled as part of the spacecraft procedure.

1.3.2.7 DC Restore Inhibit Command

The APS can be commanded to inhibit the on-board analog DC restore function for a number of scans. The DC restore function may be allowed to run continuously (which is the default setting), can be continuously inhibited, or can be allowed to operate for *n* scans and inhibited for *m* scans, where *n* and *m* can each be up to 255 scans. The DC_RESTORE_INHIBIT command is used in conjunction with the DC_RESTORE_ACTIVE command; see section 1.3.2.8. The reason for inhibiting the DC restore is to evaluate how much the DC level is drifting within an APS scan. This cannot be detected currently by looking at pre- and post-dc restore dark levels because the drift over a single scan is less than 0.001 DN (0.0005 DN/sec). However, by inhibiting the DC restore for 255 scans it is possible to detect the drift and characterize it.

The DC restore function charges a capacitor to a DC voltage that cancels the offset of the PM preamplifiers output when viewing the dark reference. This function is performed as the APS scans the center of the dark reference view. This provides a voltage datum for each channel against which the measurements are taken. If the DC restore function is inhibited, then the capacitor voltage is not changed and measurement uses the same voltage datum for the number of scans given by the DC restore inhibit command. The default value is DC restore operates normally.

1.3.2.8 DC Restore Active Command

If DC_RESTORE_INHIBIT is zero (Disabled), DC Restore is not active regardless of the value in the DC_RESTORE_ACTIVE command. If DC_RESTORE_INHIBIT is non-zero, the DC Restore is inhibited for the number of scans defined in the DC_RESTORE_INHIBIT command and is active for the number of scans defined in the DC_RESTORE_ACTIVE command. The maximum allowed is 255 for inhibit and for active.

2 Aerosol Polarimetry Sensor Data Description

2.1 Health and Engineering

There are two sources of APS health and engineering data: passive temperature telemetry and state of health telemetry. The state of health telemetry (referred to as telemetry) is provided in a single CCSDS packet which is collected by the spacecraft over the spacecraft 1553 bus.

2.1.1 Passive Temperature Telemetry

The spacecraft monitors four temperature sensors directly. These temperature measurements are NOT included in the APS data stream since they are part of the spacecrafts telemetry. Their primary use is during launch and early operations for monitoring APS temperatures while the sensor is off. There is one set of primary and redundant temperature sensors each on the: scan motor, inside the mainframe, near the polarized reference (or optical bench), and on the calibrator assembly. The numerical designator for these passive temperature sensors is T10X where X runs from 0-7 with even values being the primary sensors and odd values the redundant sensors. All of the passive sensors that are monitored by the spacecraft are directly duplicated by sensors that are read out by the APS and are included in the APS data stream except for the EM/MF. The EM/MF passive sensors track the T0X APS sensors, where X takes values from 1-8 depending on the location of sensor and whether it is a primary (even) or redundant (odd) sensor. These sensors are located on the power supply EM slice that is closest to the MF base.

2.1.2 State of Health Telemetry

The state of health telemetry data contains information about the state of health of the APS. This includes the set command parameters of the APS, the receipt of commands and time information over the 1553, the voltage drawn by different components, scan control data, signal processing information, and temperature data. This data is contained in a single CCSDS packet together with Attitude Control System data from the spacecraft and is updated each scan which is approximately every 1.47 seconds.

Table III. State of Health Overview

Telemetry Information	**Overview**
1553 data	This information includes: ·The number of accepted commands, the number of rejected commands, the last, or current, command accepted, the number of consecutive APS ACS status packets missed since the last one arrived assuming one should arrive each second.
Scan control data	This information includes the motor current, encoder values, scan control rate, scan error, and scan status.
Secondary voltages	This information includes voltages to all the Circuit Card Assemblies (CCAs) (Auxiliary, Digital Processor, Scan Control and Signal Processor) and the motor.
Set command parameters	This information includes set command parameters for each of the 12 commands.
Signal processing	This information includes Analog to Digital Converter (ADC) reference values for all bands.
Temperature	The APS monitors and telemeters 26 temperature sensors (of which 13 are internal to the EM) when operating. All EM thermistors are located on the associated primary or redundant CCA, however, the locations of the PRI and RDT thermistors on the Signal Processor and Auxiliary CCA are in slightly different locations because the printed wiring board (PWB) itself is not redundant. (See Appendix B4, Figure 29 and Figure 30.) Figure 6 illustrates the approximate location of all temperature sensors and Figure 7 shows the operational and survival heaters. Further information regarding temperature sensors can be found in section 5.1, section 5.2.1, and in Appendix B.

2.1.3 Science Data

For each scan the science data is organized into 23 stand-alone CCSDS packets that contain the data from the APS detectors collected over the entire scan at 322 sectors. In addition the last 16 bit unsigned integer in each science data packet is a number indicating which type of data is in the packet. Since the APS science data is stored as 16 bit unsigned integers the 322 sectors, with 36 pieces of data for each sector, exactly fill the 23 packets (see next section).

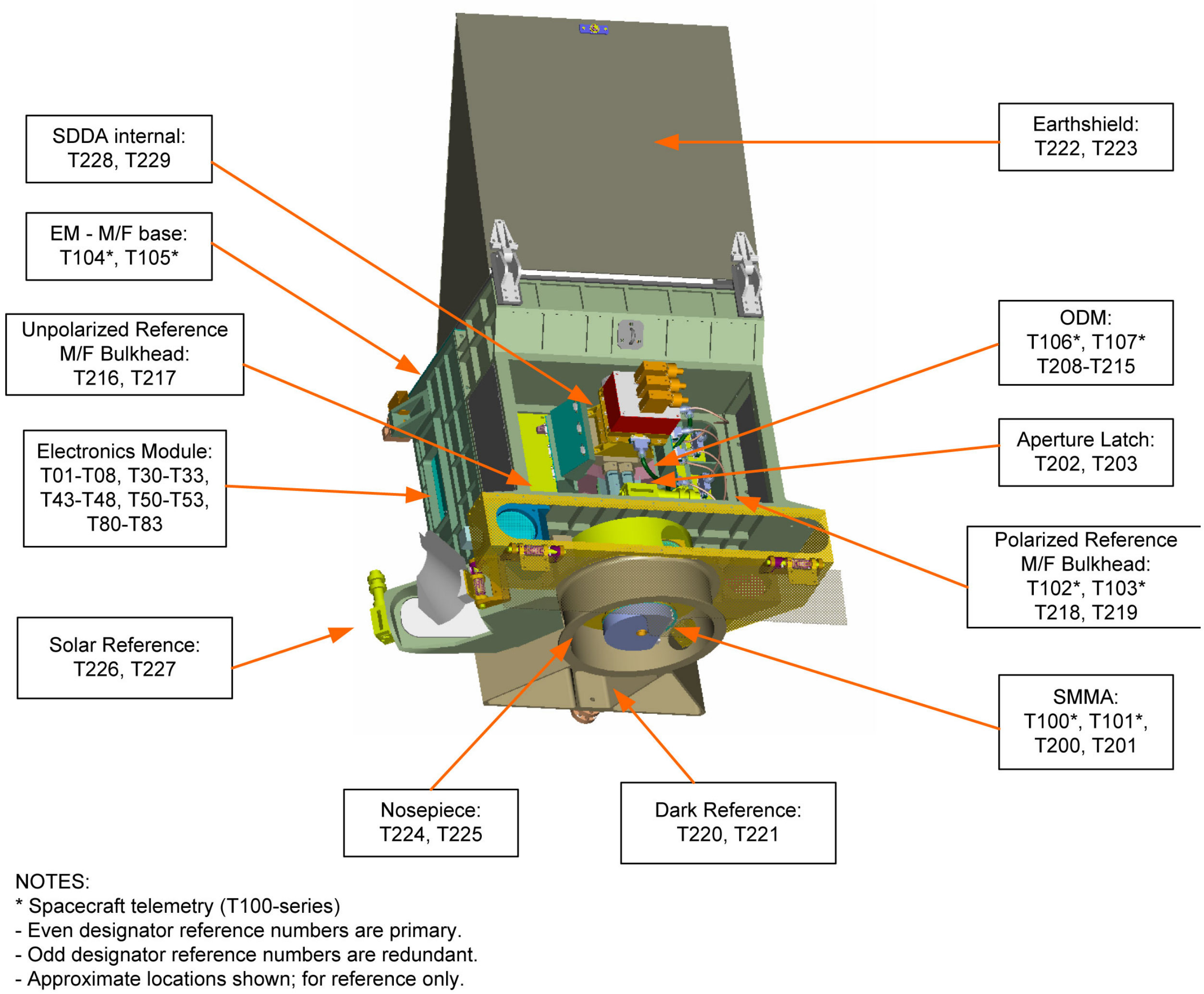

Figure 3. Schematic of thermistor locations in the APS.

2.2 Data Packet Structure

The state of health and science data packets have the same overall format structure and this is illustrated in Figure 4. The state of health and science data packets have an application process identification (APID) number of 1299. The data fields are different but all are the same length of 1010 bytes. This means that all packets sent by the APS are 1024 bytes in total length once the headers are included.

<table>
<tr><td colspan="7">Primary Header</td><td rowspan="2">Secondary Header</td><td rowspan="2">APS Data Field</td></tr>
<tr><td colspan="4">Packet Identification</td><td colspan="2">Packet Sequence Control</td><td rowspan="2">Packet Length
(16)</td></tr>
<tr><td>Version
‘000’
(3)</td><td>Type
‘1’
(1)</td><td>Secondary Header Flag
(1)</td><td>Application Process ID
(11)</td><td>Sequence Flags
(2)</td><td>Sequence Count
(14)</td><td>Time Code
(64)</td><td>(8080)</td></tr>
</table>

Figure 4. APS CCSDS header and data field structure.

The time code in the secondary header uses the first 32 bits to define the number of seconds since the start of the GPS epoch, the next 20 bits define the sub-seconds and the last 12 bits are unused. Parenthetic numbers are the number of bits assigned to each quantity. These primary and secondary headers have identical structure to the Cloud Camera CCSDS primary and secondary headers and this allows the packets to be read with a generic function that then passes the sensor and packet unique data to an appropriate function for conversion/interpretation. As described above there are 24 APS CCSDS packets with an application process ID of 1299 that contain the data from a single scan that takes 1.47 seconds.

Packet 0	Packet 1	Packet 2	………	Packet 22	Packet 23
State of Health	Science	Science		Science	Science
1024 Bytes	1024 Bytes	1024 Bytes		1024 Bytes	1024 Bytes

Figure 5. Data packet format for a single scan. Total number of bytes in a scan is 24*1024=24,576 Bytes

2.2.1 State of Health Telemetry - Packet 0

The last sixteen bits in this packet are an unsigned integer with the value 0. The values within the data field of this packet are described in Tables IV and V. In particular Table IV describes the voltages, currents and instrument states that are telemetered. A list of the conversion formulae that apply to each telemetry point and the location of the temperature sensors is given in Table V and the equations themselves are given in Table VI. Spare values are defined as telemetry addresses that are inoperative or unused and for which telemetry data can be ignored. Unused bits within defined telemetry words are set to 0. In the following the entries in the source column in the table are AUX = auxiliary CCA, SP = signal processor CCA, DP = digital processor CCA, SC = scan control CCA and GS = Glory spacecraft.

The following information is extracted from the APS instrument to spacecraft interface control document and defines the information being passed from the spacecraft attitude control system and which is included in the state of health telemetry packet in addresses 263-301.

1) All floating point values conform to ANSI/IEEE Standard 754-1985, Single-Precision float (32 bits).
2) The apparent sun unit vector is defined to be the sun vector given by attitude control system with an accuracy requirement (3-sigma) as follows: X - 150 arc-sec, Y - 1050 arc-sec and Z - 450 arc-sec .
3) The quaternian is defined as, q= [q1, q2, q3, q4], the quaternian describes the spacecraft orientation relative to the ECI Frame (J2000) with q4 as the scalar.
4) The spacecraft rate is given as rates about s/c body x-axis, y-axis and z-axis.
5) The reference EPOCH for ECI frames is J2000.
6) Delta Time is the difference between the 1pps off of the GPS receiver and the 1 Hz generated by the clock card. Delta Time Invalid implies stale data. In practice the clock is reset on the dark side of orbits when Delta_time is larger than a few msec so

although this parameter can and should be checked it is only likely to take on large values if the GPS receiver fails and is no longer in use.

Table IV. Structure of state of health telemetry packet and description of telemetry points.

Address	Source	Name		Description
0-2		CCSDS Primary Header		
3-6		CCSDS Secondary Header		
7	AUX	APS_AUX_P15V		15V to AUX
8	AUX	APS_AUX_N15V		-15V to AUX
9-10		Spare		
11	AUX	APS_SC_P15V		15V to SC
12	AUX	APS_SC_N15V		-15V to AUX
13	AUX	APS_SC_MTR_CUR		Motor current
14	AUX	APS_SC_ P30V		30V to SC
15	AUX	Spare		
16	AUX	APS_SP_PRI_RDT		> 4 V if SP Relay set to PRI, < 1 V if SP Relay set to RDT, else unknown
17-21		Spare		
22	AUX	APS_AUX_REF_GND_1		AUX reference ground
23	AUX	APS_DP_ P5V		5V to DP
24	AUX	APS_DP_ P2-5V		2.5V to DP
25	AUX	APS_SDDA_HTR_PWR		SDDA heater power. Max = 15V
26	AUX	APS_SDDA_TEMP_ERR		SDDA temp error; half the difference between SDDA set point temperature voltage and SDDA PRT temperature voltage
27	AUX	APS_SDDA_P5V		5V to SDDA
28	AUX	APS_T228	APS_T229	SDDA temperature: See Table XIX and Table XX for temperature sensor information.
29	AUX	APS_AUX_REF_GND_2		AUX reference ground
30	AUX	APS_SDDA_N5V		-5V to SDDA
31	AUX	APS_SDDA_P10V		10V to SDDA
32-36		Spare		
37	AUX	APS_PRI_RDT		5 ± 0.1 V if EM set to PRI, < 1 V if EM set to RDT, else unknown
38	AUX	APS_AGND		APS analog ground
39	AUX	APS_T200	APS_T201	
40	AUX	APS_T202	APS_T203	
41	AUX	Spare	Spare	
42	AUX	Spare	Spare	
43	AUX	APS_T208	APS_T209	
44	AUX	APS_T210	APS_T211	
45	AUX	APS_T212	APS_T213	
46	AUX	APS_T214	APS_T215	
47	AUX	APS_T216	APS_T217	
48	AUX	APS_T218	APS_T219	
49	AUX	APS_T220	APS_T221	
50	AUX	APS_T222	APS_T223	
51	AUX	APS_T224	APS_T225	

Address	Source	Name		Description
52	AUX	APS_T226	APS_T227	
53	AUX	APS_AUX_REF_1		AUX reference 3.01K
54	AUX	APS_AUX_REF_2		AUX reference 7.5K
55	AUX	APS_T02	APS_T01	
56	AUX	Spare	APS_T03	
57	AUX	APS_T06	APS_T05	
58	AUX	APS_T08	APS_T07	
59	AUX	APS_T30	APS_T31	
60	AUX	APS_T32	APS_T33	
61	AUX	APS_T50	APS_T51	
62	AUX	APS_T52	APS_T53	
63	AUX	APS_T80	APS_T81	
64	AUX	APS_T82	APS_T83	
65	AUX	APS_T46	APS_T45	
66	AUX	APS_T48	APS_T47	
67	AUX	APS_T44	APS_T43	
68		Spare		
69	AUX	APS_AUX_REF_3		AUX reference 4.99K
70	AUX	APS_AUX_REF_4		AUX reference 8.86K
71	SP	APS_BAND_1_SP_P10V		SP Band 1 +10 V
72	SP	APS_BAND_2_SP_P10V		SP Band 2 +10 V
73	SP	APS_BAND_3_SP_P10V		SP Band 3 +10 V
74	SP	APS_BAND_4_SP_P10V		SP Band 4 +10 V
75	SP	APS_BAND_5_SP_P10V		SP Band 5 +10 V
76	SP	APS_BAND_6_SP_P10V		SP Band 6 +10 V
77	SP	APS_BAND_7_SP_P10V		SP Band 7 +10 V
78	SP	APS_BAND_8_SP_P10V		SP Band 8 +10 V
79	SP	APS_BAND_9_SP_P10V		SP Band 9 +10 V
80	SP	APS_BAND_1_SP_N11V		SP Band 1 -11 V
81	SP	APS_BAND_2_SP_N11V		SP Band 2 -11 V
82	SP	APS_BAND_3_SP_N11V		SP Band 3 -11 V
83	SP	APS_BAND_4_SP_N11V		SP Band 4 -11 V
84	SP	APS_BAND_5_SP_N11V		SP Band 5 -11 V
85	SP	APS_BAND_6_SP_N11V		SP Band 6 -11 V
86	SP	APS_BAND_7_SP_N11V		SP Band 7 -11 V
87	SP	APS_BAND_8_SP_N11V		SP Band 8 -11 V
88	SP	APS_BAND_9_SP_N11V		SP Band 9 -11 V
89	SP	APS_BAND_1_SP_P5V		SP Band 1 +5 V
90	SP	APS_BAND_2_SP_P5V		SP Band 2 +5 V
91	SP	APS_BAND_3_SP_P5V		SP Band 3 +5 V
92	SP	APS_BAND_4_SP_P5V		SP Band 4 +5 V
93	SP	APS_BAND_5_SP_P5V		SP Band 5 +5 V
94	SP	APS_BAND_6_SP_P5V		SP Band 6 +5 V
95	SP	APS_BAND_7_SP_P5V		SP Band 7 +5 V
96	SP	APS_BAND_8_SP_P5V		SP Band 8 +5 V
97	SP	APS_BAND_9_SP_P5V		SP Band 9 +5 V

Address	Source	Name	Description
98	SP	APS_BAND_1_SP_VREF	Band 1 ADC voltage reference
99	SP	APS_BAND_2_SP_VREF	Band 2 ADC voltage reference
100	SP	APS_BAND_3_SP_VREF	Band 3 ADC voltage reference
101	SP	APS_BAND_4_SP_VREF	Band 4 ADC voltage reference
102	SP	APS_BAND_5_SP_VREF	Band 5 ADC voltage reference
103	SP	APS_BAND_6_SP_VREF	Band 6 ADC voltage reference
104	SP	APS_BAND_7_SP_VREF	Band 7 ADC voltage reference
105	SP	APS_BAND_8_SP_VREF	Band 8 ADC voltage reference
106	SP	APS_BAND_9_SP_VREF	Band 9 ADC voltage reference
107	DP	APS_SYSTEM_MODE	Bit 0: System Mode 0 = Safe (Default) 1 = Operational
108	DP	APS_INTEG_SET	Bits 1:0 SP Integration Select 00 = Nominal Integration (0.96 ms, or 50%) (Default) 01 = Short Integration (0.768 ms or 40%) 10 = Long Integration (1.152 ms or 60%)
109	DP	APS_SCIENCE_PKT_EN	Bit 0: Science Packet Enable 0 = Disable science packets 1 = Enable science packets (Default)
110	DP	APS_SELF_TEST_EN	Bit 0: Self Test Enable 0 = Sample normal SP data (Default) 1 = Sample self test pattern
111	DP	APS_TEMP_SETPOINT	Bits 1-0: SDDA Temp Setpoint 00 = Disable SDDA thermal control (Default) 01 = 160K 10 = 165K 11 = 155K
112	DP	APS_SAFE_EN_MISSED	Bits 9-8: Number of consecutive missed ACS (integer range 0-3). Increments each second an ACS packet was not received or accepted. Rolls over to zero if at maximum count. Reset value is zero. Resets to zero on entry to operational mode or when an ACS packet has been received and accepted. Bit 0: Enable Safe on Missed ACS 0 = Autonomous Safe Disabled (Default) 1 = Autonomous Safe Enabled.
113	DP	APS_DCR_INHIBIT	Bit 9: DC Restore State 0 = DC Restore is active in this scan (Default) 1 = DC Restore is inhibited in this scan Bit 8: DC Restore Inhibit State 0 = DC Restore Inhibit is disabled in this scan (Default) 1 = DC Restore Inhibit is enabled in this scan DC Restore Inhibit is controlled by command or via the DP test connector. Bits 7-0: DC Restore Inhibit Period (integer range 0-255) 0 = Disabled (Default) 1-255 (decimal) = Number of scans (m) DC Restore is inhibited

Address	Source	Name	Description
114	DP	APS_DCR_ACTIVE	Bits 15-8: DC Restore Count (integer range 0-255) Following the scan immediately after the DC Restore Inhibit command is written, the DC Restore Count will contain the DC Restore Inhibit Period (m) and count down; each subsequent scan will decrement this value by one until it is zero. It will then reset to the DC Restore Active Period (n) and count down; each subsequent scan will decrement this value by one until it is zero. This countdown cycle then repeats continuously. Bits 7-0: DC Restore Active Period (integer range 0-255) 0 = Disabled (Default) 1-255 (decimal) = Number of scans (n) DC Restore is active
115	DP	APS_SCAN_ COMMAND_WORD_HI	Bits 11-8: Scan Command Count Bits 7-0: Scan Command Word (high portion) The scan command count will increment every time a valid Scan command pair is received. Rolls over when maximum number is reached. Last valid command word (high portion) received
116	DP	APS_SCAN_ COMMAND_WORD_LO	Bits 7-0: Scan Command Word (low portion) Last valid command word (low portion) received.
117	DP	APS_ADC_CONV_PH	See ADC Convert Phase Adjust (integer range 0-31) Value 0 = The ADC Convert edge is aligned with the P/S clock (Default) Value 1-31 = The ADC Convert edge is delayed by the specified number of 16 MHz clock cycles
118	DP	APS_SP_RESET_CONTROL	Bits 1-0: Control state of the rising and falling edges of the SP reset pulse. 00 = Default 01 = Delay falling edge. 10 = Move up rising edge. 11 = Move up rising edge, delay falling edge.
119-122	DP	Spare	
123	DP	APS_TOD_SEC_HI	These registers are used for the CCSDS timecodes. They are updated at the start of each packet, and are then copied into the CCSDS secondary header. All values reset to zero at power-up, and are normally updated using the ACS timecode and the One PPS signal.
124	DP	APS_TOD_SEC_LO	
125	DP	APS_TOD_SUBSEC_HI	
126	DP	APS_TOD_SUBSEC_LO	
127-138		Spare	
139	DP	APS_SP_ADC_1	These registers hold the SP ADC values so they can be copied into the Science and Telemetry packets. They update whenever the Signal Processor ADCs are sampled. All values reset to zero at power up.
140	DP	APS_SP_ADC_2	
141	DP	APS_SP_ADC_3	
142	DP	APS_SP_ADC_4	
143	DP	APS_SP_ADC_5	
144	DP	APS_SP_ADC_6	
145	DP	APS_SP_ADC_7	
146	DP	APS_SP_ADC_8	
147	DP	APS_SP_ADC_9	
148	DP	APS_TEST_MODE_CMD	Bits 7-6: Monitor Select Bits 5-0: BTST_Code
149	DP	RATE_DAC_TEST_VAL	Bit 15 Rate DAC Test Enable, 0 = Normal operation 1 = Rate DAC manually controlled by Scan Control FPGA

Address	Source	Name	Description
			Bits 11-0: Rate DAC test value
150	DP	START_OF_SCAN_OFFSET	Bits 9-0: Start of scan position offset relative to rising edge of the index.
151	DP	RATE_ERROR	Bits 11-0: Current rate error value.
152	DP	APS_SCAN_IND_CNT	This is the number of edges (both rising and falling) found on Inc_A and Inc_B since the last rising edge of the encoder index signal. Reset value is zero.
153	DP	APS_SCAN_DELTA_CNT	This is the number of 16 MHz clock cycles since the last edge (rising or falling) on either Inc_A or Inc_B. If no edge has been received for at least 65535 clock cycles, this register will saturate at 65535 (0xFFFF).
154	DP	APS_SCAN_STATUS	Bit 15: 0 = BTST Scan OFF, 1 = BTST Scan ON Bit 14: 0 = BTST Stow OFF, 1 = BTST Stow ON Bit 13: 0 = BTST Rate En OFF, 1 = BTST Rate En ON Bit 12: 0 = BTST Rate Int En OFF, 1 = BTST Rate Int En ON Bit 11: 0 = BTST Pos En OFF, 1 = BTST Pos En ON Bit 10: 0 = BTST Pos Int En OFF, 1 = BTST Pos Int En ON Bits 9-5: Unused Bit 4: 0 = Not in stow position, 1 = in stow position Bit 3: 0 = Analog power not detected, 1 = Analog power detected Bit 2: 0 = Motor phases not connected, 1 = Motor phases connected Bit 1: 0 = Motor is not stopped, 1 = Motor is stopped. Bit 0: 0 = Motor is not running or has not stabilized, 1 = Motor is running and is stable
155	DP	APS_LAST_CMD	The last good command received, or the last bad command received (checksum errors only), or the invalid word of the last bad command (except checksum)
156	DP	APS_NUM_GOOD_CMD	Bits 4-0: Good Command Count (integer range 0-31) Increments each time a command was received and accepted. Rolls over to zero if at maximum count. Reset value is zero.
157	DP	APS_NUM_BAD_CMD	Bits 10-8: Failed Command Location (integer range 0-4) Indicates the word position of the command error. Values are: 0 = Error in first word (CCSDS version, type, sec header flag, APID) 2 = Error in third word (Invalid packet length, should be 3) 4 = Invalid checksum (XOR of all bytes should be 0xFF) Other values are invalid. Reset value is zero. Bits 4-0: Failed Command Count (integer range 0-31) Increments each time a command was received but not accepted. Rolls over to zero if at maximum count. Reset value is zero.
158	DP	APS_SCAN_CNT	Count of the number of scans since power up. Includes both real scans and virtual scans (when in safe mode). Value rolls over to zero when at maximum count. Reset value is zero.
159	DP	Spare	Value is always 1
160	DP	APS_INCOMPLETE_SCI_DATA	Increments each scan where not all of the science packets were read. (A science packet is considered "read" if a science poll was received and a new poll value was returned). Rolls over to zero if incremented when at maximum count. Reset value is zero.

Address	Source	Name	Description
161	DP	APS_FAILED_ACS	Bits 9-8: Failed ACS Location (integer range 0-3) Indicates the word position of the ACS error. Values are: 0 = Error in first word (CCSDS version, type, sec header flag, APID) 2 = Error in third word (Invalid packet length, should be 0x79) Other values are invalid. Reset value is zero. Bits 4-0: Failed ACS Count (integer range 0-31) Increments each time an ACS was received but not accepted. Rolls over to zero if at maximum count. Reset value is zero.
162	DP	APS_NUM_MISSED_PPS_ACS	Bits 15-8: Missed Tics (One PPS) count (integer range 0-255) Increments each second a One PPS rising edge was not received. Rolls over to zero if at maximum count. Reset value is zero. Resets to zero on entry to operational mode. Bits 7-0: Missed ACS Count (integer range 0-255) Increments each second an ACS packet was not received or accepted. Rolls over to zero if at maximum count. Reset value is zero. Resets to zero on entry to operational mode.
163	DP	APS_SCAN_STOW_POSITION	Bits 15-13: Unused Bits 12-0: Stow position relative to rising edge of the index.
164	DP	APS_INDEX_EDGE_COUNT	Bits 15-0: Increments every rising index edge. Rolls over at maximum value.
165-166		Spare	
167	DP	APS_FPGA2_SYN_SIGNATURE	This is the FPGA 2 signature at time of synthesis; value is 6.
168	DP	APS_FPGA2_SYN_SIGNATURE	This is the FPGA 2 signature at time of synthesis; value is 17.
169	DP	APS_FPGA1_SYN_SIGNATURE	This is the FPGA 1 signature at time of synthesis; value is 6.
170	DP	APS_FPGA1_SYN_SIGNATURE	This is the FPGA 1 signature at time of synthesis; value is 17.
171	SC	APS_SC_RATE_ERROR	Current rate error value
172	SC	APS_SC_SCAN_INDEX_CNT	Number of encoder pulses since the index rising edge
173	SC	APS_SC_SCAN_DELTA_CNT	Number of 16 MHz clock cycles since last encoder edge
174	SC	APS_SC_SCAN_STATUS1	Bits 15-4: Unused (read as zero) Bit 3: 0 = Analog power not detected, 1 = Analog power detected Bit 2: 0 = Motor phases not connected, 1 = Motor phases connected Motor is normally only connected when APS is in Operational mode. If Spacecraft power is removed when APS is in Operational mode, the motor will still be connected upon the next power up of the instrument. Bit 1: 0 = Motor is not stopped, 1 = Motor is stopped Bit 0: 0 = Motor is not running or has not stabilized, 1 = Motor is running and is stable
175-262	SC		Repeats 171-174 for the beginning of every science packet in a scan

263-266	GS	Spacecraft_Time	Time of Sun Position and Spacecraft Attitude packet creation. Time encoding is same as CCSDS secondary header.
267-272	GS	Spacecraft_Position	Spacecraft position in ECI frame. 3 floating point numbers in IEEE 754 format. Unit is meters.
273-278	GS	Spacecraft_Velocity	Spacecraft velocity in ECI frame. 3 floating point numbers in IEEE 754 format. Unit is meters/second.
279-286	GS	Spacecraft Attitude	Spacecraft Quaternion Estimate. 4 floating point numbers in IEEE 754 format. Unit is dimensionless.
287-292	GS	Spacecraft Rate	Spacecraft rate estimate in spacecraft body frame 3 floating point numbers in IEEE 754 format. Unit is rad/sec.

293-298	GS	Sun_Position	Apparent sun unit vector in spacecraft body frame components. 3 floating point numbers in IEEE 754 format. Unit is dimensionless. x-direction is the velocity vector, z-direction is nadir in a right handed co-ordinate system.[1]
299	GS	Sun_Present	16-bit, unsigned integer (0 = eclipse, 1 = sun)
300	GS	Delta_Time	1PPS to 1 hertz; 2's Complement; Bit 0 = 1 when valid.
301	GS	Spacecraft_ID	8 LSBs
302-510		Spare	
511	DP	Packet_Number	APS Data packets are numbered 0-23 with the state of health packet = 0.

Table V. Conversion formulae codes to be applied to each telemetry point together with location/description of temperature sensors.

Address	Name	Conversion Equation	Description
7	APS_AUX_P15V	E	AUX CCA +15V Supply
8	APS_AUX_N15V	E	AUX CCA -15V Supply
11	APS_SC_P15V	F	SC CCA +15V Supply
12	APS_SC_N15V	E	SC CCA -15V Supply
13	APS_SC_MTR_CUR	T	SC Motor Current
14	APS_SC_P30V	H	SC CCA +30V Supply
16	APS_SP_PRI_RDT	G	Signal Processor Primary/Redundant Flag
22	APS_AUX_REF_GND1	G	AUX CCA Reference Ground
23	APS_DP_P5V	I	DP CCA +5V Supply
24	APS_DP_P2_5V	G	DP +2.5V Supply
25	APS_SDDA_HTR_PWR	J	SDDA Heater Power (W)
26	APS_SDDA_TEMP_ERR	D	SDDA Temperature Error (K)
27	APS_SDDA_P5V	I	SDDA +5V Supply
28	APS_T228_229	C	SDDA Temperature
29	APS_AUX_REF_GND2	G	AUX CCA Reference Ground
30	APS_SDDA_N5V	I	SDDA -5V Supply
31	APS_SDDA_P10V	K	SDDA +10V Supply

37	APS_PRI_RDT	G	APS Primary/Redundant Flag
38	APS_AGND	G	APS Analog Ground
39	APS_T200_201	A	Motor temperature (internal)
40	APS_T202_203	A	Aperture door latch temperature.
43	APS_T208_209	A	Exterior of SDDA
44	APS_T210_211	A	Top of optics detector module, rear.
45	APS_T212_213	A	Top/bottom of optics detector module, front right.
46	APS_T214_215	A	Top/bottom of optics detector module, front left.
47	APS_T216_217	A	Unpolarized reference mainframe bulkhead
48	APS_T218_219	A	Polarized reference mainframe bulkhead
49	APS_T220_221	A	Dark reference
50	APS_T222_223	B	Earth shield
51	APS_T224_225	A	Scan mirror assembly nose piece
52	APS_T226_227	A	Solar reference latch
53	APS_AUX_REF_1	P	AUX Reference current through 3.01 KOhm
54	APS_AUX_REF_2	Q	AUX Reference current through 7.5 KOhm
55	APS_T02_01	A	Power supply brick 6 ±15V
56	APS_T04_03	A	Power supply brick 1 ±15V
57	APS_T06_05	A	J75 connector on power supply CCA
58	APS_T08_07	A	J41 connector in power supply CCA
59	APS_T30_31	A	Center of AUX CCA
60	APS_T32_33	A	Power supply brick 7/8 +5V
61	APS_T50_51	A	Digital processor CCA, top right
62	APS_T52_53	A	Digital processor CCA, bottom
63	APS_T80_81	A	Motor hybrid on SC CCA

64	APS_T82_83	A	SC CCA, top left
65	APS_T46_45	A	Top/bottom of Digital Signal Processor CCA
66	APS_T48_47	A	Left edge of Digital Signal Processor CCA
67	APS_T44_43	A	ADC on Digital Signal Processor CCA
69	APS_AUX_REF_3	R	AUX Reference current through 4.99 KOhm
70	APS_AUX_REF_4	S	AUX Reference current through 8.86 KOhm
71	APS_BAND_1_SP_P10V	L	SP Band 1 +10V
72	APS_BAND_2_SP_P10V	L	SP Band 2 +10V
73	APS_BAND_3_SP_P10V	L	SP Band 3 +10V
74	APS_BAND_4_SP_P10V	L	SP Band 4 +10V
75	APS_BAND_5_SP_P10V	L	SP Band 5 +10V
76	APS_BAND_6_SP_P10V	L	SP Band 6 +10V
77	APS_BAND_7_SP_P10V	L	SP Band 7 +10V
78	APS_BAND_8_SP_P10V	L	SP Band 8 +10V
79	APS_BAND_9_SP_P10V	L	SP Band 9 +10V
80	APS_BAND_1_SP_N11V	M	SP Band 1 -11V
81	APS_BAND_2_SP_N11V	M	SP Band 2 -11V
82	APS_BAND_3_SP_N11V	M	SP Band 3 -11V
83	APS_BAND_4_SP_N11V	M	SP Band 4 -11V
84	APS_BAND_5_SP_N11V	M	SP Band 5 -11V
85	APS_BAND_6_SP_N11V	M	SP Band 6 -11V
86	APS_BAND_7_SP_N11V	M	SP Band 7 -11V
87	APS_BAND_8_SP_N11V	M	SP Band 8 -11V
88	APS_BAND_9_SP_N11V	M	SP Band 9 -11V
89	APS_ABND_1_SP_P5V	N	SP Band 1 +5V
90	APS_ABND_2_SP_P5V	N	SP Band 1 +5V

91	APS_ABND_3_SP_P5V	N	SP Band 1 +5V
92	APS_ABND_4_SP_P5V	N	SP Band 1 +5V
93	APS_ABND_5_SP_P5V	N	SP Band 1 +5V
94	APS_ABND_6_SP_P5V	N	SP Band 1 +5V
95	APS_ABND_7_SP_P5V	N	SP Band 1 +5V
96	APS_ABND_8_SP_P5V	N	SP Band 1 +5V
97	APS_ABND_9_SP_P5V	N	SP Band 1 +5V
98	APS_BAND1_V_REF	O	Band 1 ADC Voltage Reference
99	APS_BAND2_V_REF	O	Band 2 ADC Voltage Reference
100	APS_BAND3_V_REF	O	Band 3 ADC Voltage Reference
101	APS_BAND4_V_REF	O	Band 4 ADC Voltage Reference
102	APS_BAND5_V_REF	O	Band 5 ADC Voltage Reference
103	APS_BAND6_V_REF	O	Band 6 ADC Voltage Reference
104	APS_BAND7_V_REF	O	Band 7 ADC Voltage Reference
105	APS_BAND8_V_REF	O	Band 8 ADC Voltage Reference
106	APS_BAND9_V_REF	O	Band 9 ADC Voltage Reference

Table VI. Conversion equations for transforming digital numbers into engineering units.

Conversion Equation	Unit	Equation
A	°C	eng_unit_out=5398.94/(14.7512038d0+alog((dn_in-32767)/(33130.2449-(dn_in-32767))))-341.0
B	K	eng_unit_out=273.15+(5.62158e-17*dn_in)-(1.19657E-07* dn_in)^2 - (5.5188116E-04*dn_in)^3 + (2.9306199E-04*dn_in)^4-(1.4957120E-04*dn_in)^5
C	K	eng_unit_out=97.03+ 0.0128*dn_in
D	K	eng_unit_out=-890.307+0.02717*dn_in
E	V	eng_unit_out=-18.6986+0.000570636*dn_in
F	V	eng_unit_out=-17.7551+0.000541842*dn_in
G	V	eng_unit_out=-5.0 + 0.000152587*dn_in

H	V	eng_unit_out=-39.0136+0.0011906*dn_in
I	V	eng_unit_out=-6.2438+0.000190545*dn_in
J	W	eng_unit_out=1.50869-0.000092083*dn_in+(3.74844E-05* dn_in)^2
K	V	eng_unit_out=-12.3383 + 3.76535e-4*dn_in
L	V	eng_unit_out=-0.421556704+0.000172917*dn_in
M*	V	eng_unit_out=(-5.0*(-0.421556704+ 0.000172917*dn_in_2)/3.0-0.508176667) + 2.08448e-4*dn_in
N	V	eng_unit_out=-0.95664498+0.000392404*dn_in
O	V	eng_unit_out=-0.952833645+0.000390841*dn_in
P	μA	eng_unit_out=-1661.02+0.05069109*dn_in
Q	μA	eng_unit_out=-666.67+0.020345052*dn_in
R	μA	eng_unit_out=-1001.957+0.03057777*dn_in
S	μA	eng_unit_out=-564.315 + 0.017221800*dn_in
T	A	eng_unit_out=-3.75+0.000114441*dn_in

* The conversion equation 'M' for the signal processor -11V telemetry point also uses the value of the signal processor +10 V for the same band to determine its value. The variable dn_in_2 in this formula is therefore the digital number for the +10V signal processor telemetry point for the same band.

2.2.2 Science Data Packets 1-23

Within each science packet there are 14 sectors, or view angles, each containing 36 measurements discretized with 16 bit precision as unsigned integers. The 36 measurements are the observations of four polarization states in each of nine spectral bands (4x9=36).

Primary Header	Secondary Header	Sector 1	………	Sector 14	Packet ID
6 Bytes	8 Bytes	72 Bytes		72 Bytes	2 Bytes

Figure 6. Format of a science data packet. Total number of bytes in a packet is 1024.

The organization of the measurements within a sector in terms of spectral band and whether they have a polarizer nominally oriented at 0° (1L), 45° (2L), 90° (1R) or 135° (2R) is described in Table VII. Although the dark offsets need to be subtracted independently for each channel and there are calibration coefficients that are required to obtain accurate Stokes vector elements *(I, Q, U)* in essence *I=1L+1R*, *Q=1L-1R*, *U=2L-2R* and the intensity measurement is redundant since it is also the case that $I=2L+2R$. A full description of how the measurements are converted into Stokes vector elements is given in the APS Calibration Algorithm Theoretical Basis Document (ATBD).

Table VII. Relative addresses of the data within the 36 unsigned 16 bit integers constituting a sector. Addresses are zero-based and run from 0-35.

	Spectral Band (nm)								
Polarization Orientation	410	443	555	673	863	910	1378	1600	2250
1L	9	19	11	21	13	23	15	16	17
1R	0	28	2	30	4	32	6	7	8
2L	27	1	29	3	31	5	33	34	35
2R	18	10	20	12	22	14	24	25	26

The content of the APS science packets, i.e. what is being viewed in any given sector, is given in Table VIII. Not all sectors that nominally view a particular calibrator/reference or Earth scene are clear. Table IX provides lower and upper limits on which data is useable for each class of sector.

Table VIII. Content of the APS science packets. Note that the sector numbering in this table assumes that the first sector has the value 1.

Packet #	Sector #	Content
1	1-14	Post DC dark sectors 1-14
2	15-28	Post DC dark sectors 15,16
		Polarized reference data sectors 1-7
		Scene data sectors 1-5
3	29-42	Scene data sectors 6-19
4	43-56	Scene data sectors 20-33
5	57-70	Scene data sectors 34-47
6	71-84	Scene data sectors 48-61
7	85-98	Scene data sectors 62-75
8	99-112	Scene data sectors 76-89
9	113-126	Scene data sectors 90-103
10	127-140	Scene data sectors 104-117
11	141-154	Scene data sectors 118-131
12	155-168	Scene data sectors 132-145
13	169-182	Scene data sectors 146-159
14	183-196	Scene data sectors 160-173
15	197-210	Scene data sectors 174-187
16	211-224	Scene data sectors 188-201
17	225-238	Scene data sectors 202-215
18	239-252	Scene data sectors 216-229

19	253-266	Scene data sectors 230-243
20	267-280	Scene data sectors 244-255
		Unpolarized reference data sectors 1-2
21	281-294	Unpolarized reference data sectors 3-11
		Solar reference sectors 1-5
22	295-308	Solar reference sectors 6-17
		Pre DC dark sectors 1, 2
23	309-322	Pre DC dark sectors 3-16

Table IX. Useable sectors for each scene/calibrator type. Sector numbers are again numbered assuming that the first sector for a given scene/calibrator has the value 1. Note that all the calibrators except the SRA have been exercised during ground testing. The range of valid scene data for the SRA will be determined on orbit and a more detailed description of which sectors are expected to be useable is given in the APS Calibration ATBD.

Useable Range	Pre-DC Dark	Post-DC Dark	URA	PRA	Scene	SRA
Low	2	4	8	4	8	1
High	15	15	9	5	255	17